Three-Dimensional Interpretation of Borehole-to-Surface Electromagnetic Data

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RESEARCH OBJECTIVES

Simulation and interpretation of 3-D electromagnetic (EM) problems are challenging tasks. The process involved is usually very time-consuming because of the large number of unknowns to solve. Consequently, the development of a simulation code of dramatically improved efficiency is essential. To this end, a new scheme dubbed the modified extended Born approximation (MEBA), has been developed for efficient 3-D simulation and interpretation of geophysical EM data.

APPROACH

Originating from the integral equation method and assuming a constant electric current density in a conductivity-anomalous region, the MEBA technique is used to calculate, without solving a huge matrix equation, the total electric field in the inhomogeneity by multiplying the background electric field with a depolarization tensor. Simulation results show that the MEBA technique yields better accuracy when current channeling dominates induction in the conductivity inhomogeneity. Fourier transform and convolution theorem have been used to improve the efficiency of the method. The MEBA method has been successfully incorporated into a 3-D inversion code, and its use in deriving the Jacobian matrix leads to improved computational efficiency.

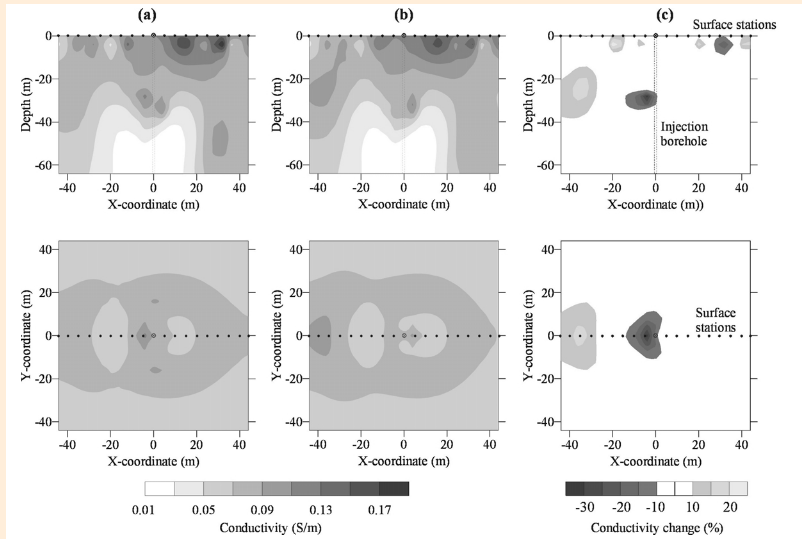

Figure 1. 3-D MEBA inversion results using (a) pre-extraction BTS data and (b) post-extraction data. The vertical section contains the transmitter well and the surface profile while the horizontal slice is at a depth of 28 m. (c) Conductivity change, in percentage with respect to the pre-extraction conductivity, due to the salt-water drawing.

ACCOMPLISHMENTS

The MEBA technique has been successfully applied to interpret borehole-to-surface (BTS) EM field data acquired at the University of California's Richmond Field Station, where a brine spill was simulated by creating a saline water injection zone at a depth of about 30 m. The plume, of which the extent was to be determined from the post-injection BTS data, was later extracted and the experiment was construed as monitoring a remediation process. The BTS data were the vertical component of the magnetic fields collected at 5 m intervals along a 110-m-long surface profile centered at the injection well, in which the transmitter was run upward from 60-m-depth to the surface. Both data sets acquired before and after the water extraction were inverted by starting with a 12 ohm-m homogeneous half space as the initial model. Figure 1a shows the interpreted pre-extraction conductivity distribution in the vertical plane containing the surface profile and the transmitter borehole, and in a horizontal slice at 28-m-depth. The corresponding post-extraction results are displayed in Figure 1b. The sections in the lower left and the lower right corners in the vertical plane should be considered as contaminated due to numerical artifacts. The two distinct units with a boundary at about 40-m-depth correspond to the interwoven sediments and the basement at the test site, respectively. The injected salt-water plume manifests itself as a small conductive region, absent in the post-extraction results shown in Figure 1b. The conductivity change due to the water removal is expressed in Figure 1c in percentage terms relative to the conductivity before the pumping. Clearly, the effect of the pumping has reduced the conductivity of the injected zone by as much as 35%.

SIGNIFICANCE OF FINDINGS

Applications of the Fourier transform and convolution theorem to the MEBA technique increase its efficiency dramatically and make EM 3-D interpretation on ordinary computing platforms practical.

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